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The Effect of Salt Solutions on Germination

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THE EFFECT
OF
SALT SOLUTIONS ON GERMINATION

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PEARL FOREST GROVE

THESIS

FOR THE

DEGREE OF BACHELOR OF ARTS

IN

SCIENCE

COLLEGE OF SCIENCE

UNIVERSITY OF ILLINOIS

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May 29, 1913

THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Pearl Forest Grove

ENTITLED The Effect of Salt Solutions on Germination.

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Arts

In General Science

Chas. F. Hottes
Instructor in Charge

APPROVED: Chas. F. Hottes

Acting HEAD OF DEPARTMENT OF Botany

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THE EFFECT OF SALT SOLUTIONS ON GERMINATION.

I. Introduction.

The relation between the growth of plants and concentration of solutions has been studied a great deal. Among those who have contributed to this subject are:- Jarius ('86), Jentys ('88), Stange ('92), Vandevelde ('97) and others. The results obtained by these investigators are far from being concordant.

1.- Investigations of Vandevelde.

The experiments of Vandevelde are especially interesting and have been considerably referred to in the general literature relative to the effect of concentration of solution on germination and growth.

His results as obtained by treating the seeds of the common pea, Pisum sativum, are so difficult to correlate that it was deemed profitable to repeat his experiments with the view of correcting or explaining the irregularities. He soaked the seeds for 24 hours in solutions of common salt varying from 1 per cent to 35 per cent and then placed them in pans for germination.

His results may be noted as follows:-

G% per cent of seeds that germinated, I, the mean interval elapsing in days before one half of the seeds germinated and % = per cent of solution.

%	G%	I
1	98.	2.1
2	97.17	3.7
3	85.17	4.0
4	34.50	4.6
5	32.66	4.8
6	16.83	5.0
7	15.33	5.2
8	14.83	5.3
9	12.66	5.4
10	12.46	5.9
11	7.00	6.6
12	10.00	6.3
13	8.50	6.8
14	7.19	6.3
15	4.50	6.7
16	6.83	7.1
17	4.76	6.6
18	3.33	6.2
19	4.00	5.7
20	5.67	5.7
21	3.33	7.0
22	1.50	5.6
23	1.83	6.2
24	4.00	5.8
25	0.83	5.8
26	4.50	6.3
27	8.17	6.8
28	6.83	5.7
29	3.83	6.7
30	10.33	6.5
31	8.33	6.8
32	10.67	7.2
33	23.00	6.3
34	31.33	6.5
35	56.83	7.0

The results as presented in this table, are discussed by Davenport as follows:- As the concentration increases from one per cent to fifteen percent, the percentage of germination diminishes from 98 to 4.5 and the mean germination interval increases from 2.1 days to nearly 7 near which point it remains at all higher concentrations. From 15 per cent to 29 per cent the percentage of germinations fluctuate so irregularily between 6.8 and 0.83 that within these limits it may be considered constant.

As the concentration increases from 29%, instead of the seeds all being killed or failing to germinate we have the interesting result that the percentage of germinating individuals rises rapidly from 4 to 56. Vandevelde hazards the following explanation of this result: "Dilute solutions are easily absorbed; the more concentrated the solution, the smaller the power of diffusion. In a saturated solution the seeds do not swell and the action of the surrounding medium is less injurious."

The apparatus used by Vandevelde for germinating the seeds consisted of porus clay plates which were covered with flannel strips dipped in water and laid in zinc containers or boxes. The whole apparatus was placed in wooden chests, which were kept in a cellar at a fairly uniform temperature.

2.- Methods.

In repeating the experiments of Vandevelde it was found best to modify his methods as follows:- All seeds were soaked before germination either in distilled water or in a salt solution of definite concentration.

Those soaked in distilled water served as checks; the others in salt solutions varying from one per cent to thirty-five per cent. The apparatus first used consisted of a covered pan furnished with moist filter paper on which were placed the seeds for germination. This method seemed to work very well for seeds soaked in weak solutions, but for solutions of higher concentration, in which delayed, the seeds would mold before germinating. Hence a method was sought that would prevent this. Zurich germinating dishes were next used, but with no better success. Next,

a pan with a piece of towling stretched across it was set in a larger pan containing water. The free ends of the towling dipped into the water and maintained the supply of moisture. The seeds were placed on the cloth and another pan inverted over the one containing the water.

The seeds which remained hard after being in the germinating pans for five or six days were removed, soaked in tap water for 24 hours. It was found that the per cent of germination of these seeds is not in the least affected by the treatment with salt solution of high concentration.

The experiments were conducted for a time in the laboratory at ordinary room temperature. The temperature fluctuated so much that it was found necessary to conduct the experiments in a room of relatively constant temperature.

Another method of germination was also used. This method is equally as good as the last one described and is as follows. Plaster-of-paris plates about six inches square and one inch thick were covered with dampened cloths and placed in a covered tub. The seeds were placed on these cloths. By this method I was enabled to use a much larger number of seeds and consequently run a considerable series under identical conditions.

The plates could be easily sterilized by heat and were more convenient than the towling which had to be stretched over the pans.

Untreated seeds, by a series of tests, demonstrated the methods of germination to be very satisfactory.

3.- Tests for percentage of germination.

The following varieties of peas were used in the experiments.

Canada field peas were first used. The seeds were soaked in distilled water for 24 hours and then placed in germinating pans with the following results:

Tests	No. Seeds used.	G%	I
1	200	97.5	1.07
2	200	97.0	2.2
2	100	97.0	2.6
		97.1	1.83 Gen. Aver.

White Marrow-fat peas were soaked in distilled water for 24 hours and then placed in germinating pans with the following results:

Test	No. Peas	G%	I
1	300	96	1.602

Telephone Peas were soaked in distilled water for 24 hours and then placed in germinating pans with the following results:

Test	No. Seeds	G%	I
1	200	96	1.32

II.- Discussion of Experiments and Results.

1.- Canada Field Peas.

(a)- First Series.- The following are the results of a series of experiments to test the germination of the Canada Field pea after having been soaked in solutions of common salt, 1 percent to 35 percent for 24 hours.

TABLE III.

%	G%	I	S. G.	%	G%	I	S. G.
1	97.78	2.32	1.0065	19	5.15	2.6	1.112
2	90.48	2.44	1.012	20	5.15	3.8	1.119
3	59.31	3.4	1.019	21	8.24	2.25	1.125
4	32.86	3.71	1.025	22	6.18	3.5	1.132
5	22.46	3.77	1.032	23	7.21	1.28	1.137
6	13.5	4.67	1.038	24	8.24	2.77	1.144
7	13.49	2.00	1.047	25	10.03	2.00	1.151
8	12.36	2.33	1.051	26	9.27	2.77	1.157
9	11.33	2.18	1.0575	27	10.3	1.8	1.164
10	11.33	2.18	1.065	28	12.36	2.25	1.170
11	5.15	2.8	1.070	29	12.36	2.25	1.170
12	6.18	2.16	1.067	30	10.3	2.31	1.189
13	6.18	2.16	1.075	31	13.4	2.23	1.196
14	4.12	4.5	1.080	32	24.9	2.33	1.202
15	11.33	3.72	1.089	33	20.6	1.95	1.209
16	3.09	2.66	1.093	34	27.8	2.07	1.215
17	5.15	2.00	1.098	35	51.5	1.6	1.221
18	6.18	1.66	1.106				

The results recorded in table III agree very closely with those of Vandevelde. This is clearly brought out in the graphs represented in Plate I.

The increased time before germination of seeds soaked in salt solutions from 1 to 6 % is due to the lower temperature at which these seeds were kept for germination. Time did not allow a repetition of these experiments.

All seeds that failed to germinate after a reasonable length

of time and still remained firm were soaked for 24 hours in tap water and placed under favorable conditions for germination. The following table shows the results of three tests of 25 firm seeds each, after they had been in a saturated solution of salt for 24 hours.

Table IV.

Tests	G%	I
1	95	1.1
2	95	1.28
3	100	1.2

This table shows, as has already been stated, that germination takes place the same as though the seeds had never been soaked in NaCl solution. In the solutions of high concentration the number of seeds germinating depends entirely upon the number that fail to take up the solutions because of the impermeable nature of the seed coats. The coats of a complex sample of seeds vary widely as to the nature of the seed coats.

The experiments show very clearly that in solutions above a certain concentration the number of seeds capable of germination depends upon the number of firm seeds in the solution after soaking for 24 hours, i.e., the number whose membranes are impermeable to the salt solution.

Plate number II shows this solution to be between ten per cent and eleven per cent, and after this concentration is passed the number of seeds that will germinate corresponds very closely with the number of firm seeds in the solution after soaking for 24 hours.

The irregularities in the curves, I believe, can be explained by the fact that the seed coats impermeable to salt solutions show a variable permeability to water. In placing such seeds on plaster blocks for germination, those only whose coats are readily permeable to water, swell and germinate.

The graphs on plate number 3 represents the results as tabulated in table number V. This shows that the seed coats less permeable to NaCl solutions will admit sufficient water for germination when immersed in it for 24 hours.

The following table shows the number of firm seeds per hundred and the germination. These were taken from solutions of common salt varying from 1% to 35%.

TABLE V.

%	H. Seeds.	G%	%	H. Seeds.	G%
1	6	6	19	10	4
2	6	6	20	7	5
3	1	1	21	9	7
4	4	3	22	8	7
5	6	5	23	9	7
6	10	10	24	8	8
7	9	8	25	12	10
8	11	11	26	10	10
9	10	9	27	15	11
10	9	7	28	15	12
11	7	7	29	14	12
12	9	8	30	14	10
13	7	7	31	14	13

%	H. S.	G%	%	H. S.	G%
14	6	5	32	27	23
15	12	11	33	22	20
16	4	3	34	22	22
17	8	6	35	45	44
18	9	7			

2000 Canada Field peas soaked in distilled water for 24 hours showed that 1% are impermeable to water.

224 seeds that failed to swell in salt solutions of from 21% to 35% were taken from the solutions and soaked in distilled water for 24, 48, 72, and 96 hours with the following results:

Table VI.

Time in hours	Seeds swollen	Total seeds	Total remaining firm.
24	148		
48	26		
72	19		
96	16	209	15

Of this number the coats of 15 were impermeable to water even after 96 hours. The above number (234) were all of the firm seeds obtained from 1500 peas soaked in salt solutions of from 21% to 35%. The number (15) remaining firm after being soaked in water 96 hours is the same percent (1%) as found in the preceeding experiment.

(b) Second series.- New Canada Field Peas were obtained together with White Marrow-fat and Telephone peas.

The germination tests were about the same for the fresher peas as they were for those of the first used. However, soaking

these peas in distilled water 24 hours I failed to obtain any hard seeds as in the first Canada Field peas previously used. The following table shows the results obtained by soaking seeds for 24 hours in salt solutions.

TABLE VII.

%	G%	I	S. G.	%	G%	I	S. G.
1	90.8	1.6	1.0062	16	0	0	1.103
2	80.8	2.2	1.0125	17	2.2	2	1.110
3	67.7	2.2	1.0755	18	2.2	3.3	1.1175
4	30.5	2.2	1.0225	25	3.3	2.3	1.154
5	15.5	2.1	1.0287	26	3.3	4.0	1.1615
6	9.9	2.2	1.0362	27	4.3	3.6	1.170
7	0	0	1.0425	28	6.0	4.0	1.175
8	0	0	1.0485	29	8.0	4.0	1.179
9	0	0	1.0537	30	16.0	3.1	1.183
10	0	0	1.058	31	28.0	3.6	1.191
11	0	0	1.062	32	32.0	3.1	1.198
12	0	0	1.069	33	37.7	3.6	1.198
13	0	0	1.077	34	36.5	3.1	1.198
14	0	0	1.091	35	41.5	3.2	1.198
15	1	1	1.098				

It is seen from this table that all of the solutions are more or less injurious. From the 5% solution all of the swelled seeds are killed. In 15% solutions we obtain one per cent germination; in 17, two per cent and in 18 five per cent. All of the seeds swelled up to fifteen per cent solution. In higher concentrations about 1% of the seeds soaked in salt solutions

failed to swell. This remained about the same at 16% and 17% solution, but arose to 5% in the 18 per cent solution.

If the seeds are soaked for 24 hours in tap water after soaking in salt solutions the time for germination is much reduced and the number of seeds to germinate is much higher. This is clear from the table that follows:

Table VIII.

%	G%	I	S. G.	%	G%	I	S. G.
1	93.9	1.2	1.006	15	1.0	1.0	1.098
2	91.7	1.4	1.012	16	0	0	1.103
3	65.0	1.5	1.017	17	2	1	1.110
4	46.4	1.8	1.022	18	5	1	1.117
5	10.0	1.9	1.028	25	12.3	1.5	1.154
6	0.0	2.0	1.036	26	16.4	1.1	1.161
7	0.0	0	1.042	27	19.5	1.1	1.170
8	0.0	0	1.048	28	28.8	1.1	1.175
9	0.0	0	1.053	29	26.8	1.1	1.178
10	0.0	0	1.061	30	27.8	1.65	1.193
11	0.0	0	1.069	31	35.0	1.7	1.195
12	0.0	0	1.077	32	37.2	1.49	1.198
13	0.0	0	1.085	33	39.1	1.6	1.198
14	0.0	0	1.091	34	49.4	1.7	1.198

2.- White Marrow-fat peas.-

The following table gives the results of soaking white marrow-fat peas in common salt solutions for 24 hours and then placing them in a pan to germinate.

TABLE IX.

%	G%	I	S. G.	%	G%	I	S. G.
1	90.0	2.8	1.006	14	6.2	4.1	1.103
2	72.4	2.2	1.012	15	1.0	4.5	1.098
3	29.89	2.2	1.017	16	6.2	4.1	1.110
4	16.0	2.2	1.022	17	5.1	4.0	1.110
5	5.0	2.0	1.028	18	8.2	4.0	1.117
6	4.0	2.8	1.036	25	16.4	4.4	1.154
7	5.0	3.0	1.042	26	14.4	4.2	1.161
8	7.0	3.0	1.048	27	17.5	3.7	1.170
9	3.0	3.0	1.053	28	26.3	3.0	1.175
10	3.0	2.0	1.062	29	27.1	3.9	1.178
11	3.0	2.0	1.069	30	28.9	4.0	1.183
12	4.0	2.5	1.077	31	27.1	3.8	1.191
13	4.0	4.0	1.085	35	33.0	3.85	1.198

This table shows some interesting results and in general agrees with the results obtained by Vandevelde. Plate Number 6 represents the curve of germination. There were some seeds in each solution that failed to swell after soaking for 24 hours in common salt solution. After passing the 4% solution the number of seeds germinating never exceeded the number of firm seeds taken from the solution. This shows that all seeds that swell in salt solutions above four per cent are killed.

When the White marrow-fat peas were soaked in tap water for 24 hours after taken from the salt solutions, a much better and quicker germination resulted, as seen from the following table.

TABLE X.

%	G%	I	S. G.	%	G%	I	S. G.
1	95.8	1.8	1.006	14	5.2	1.4	1.085
2	75.0	1.7	1.012	15	3.1	2.0	1.098
3	37.5	1.7	1.022	16	5.2	1.0	1.103
4	18.7	1.6	1.028	17	5.2	1.4	1.111
5	6.25	1.3	1.032	18	8.3	2.0	1.1175
6	5.2	2.0	1.036	25	21.8	1.7	1.154
7	4.1	1.0	1.042	26	21.8	1.2	1.161
8	5.2	1.0	1.048	27	21.8	1.6	1.170
9	5.2	1.3	1.053	28	28.0	1.7	1.075
10	3.1	1.3	1.059	29	31.2	2.0	1.178
11	3.1	1.0	1.062	30	28.0	1.5	1.183
12	4.1	1.5	1.069	31	32.2	1.5	1.191
13	4.1	1.0	1.079				

This table is represented in the curve of plate number 7. It shows the same general tendency of high germination in the low per cent solutions, a rapid falling off to five per cent then remaining nearly constant to 18 per cent.

Since large numbers of seeds were required in order to make sure of correct results it was thought best to discontinue this series of experiments at 18% solution and go to 25% solution. The curve shows a considerable rise in germination from 18% to 25%.

The dotted line shows the probable rise in germination between these two solutions. At any rate it is safe to say that the rise in germination is rather rapid between these two solu-

tions and remains quite uniform until 31% solution is reached. Here the experiments were discontinued for this series.

3.-Telephone Peas.

Telephone peas were also tested for germination after being soaked in salt solutions of various concentrations as follows:

TABLE XI.

%	G%	I	S. G.	%	G%	I	S. G.
1	90.6	1.6	1.006	14	0.0	0.0	1.091
2	88.0	1.3	1.012	15	1.0	3.0	1.098
3	68.7	1.3	1.017	16	0.0	0.0	1.103
4	43.1	1.7	1.022	17	0.0	0.0	1.110
5	8.3	2.3	1.028	18	1.0	4.0	1.117
6	0.0	0.0	1.036	25	2.0	3.0	1.154
7	0.0	0.0	1.042	26	3.1	3.0	1.161
8	0.0	0.0	1.048	27	3.1	3.0	1.170
9	0.0	0.0	1.053	28	3.1	2.6	1.175
10	0.0	0.0	1.060	29	5.2	3.0	1.178
11	0.0	0.0	1.069	30	9.3	4.0	1.183
12	0.0	0.0	1.077	31	9.3	4.0	1.191
13	0.0	0.0	1.085	35	10.5	3.5	1.198

From this table it is evident that one and two per cent solutions have little effect on germination of the seeds, that germination decreases very rapidly, and from 6 to 15% solutions all germs are killed. One per cent of the peas soaked in 15% solution germinated. In a 16% solution and a 17% solution no seeds germinated. The number germinating after soaking in solutions of NaCl

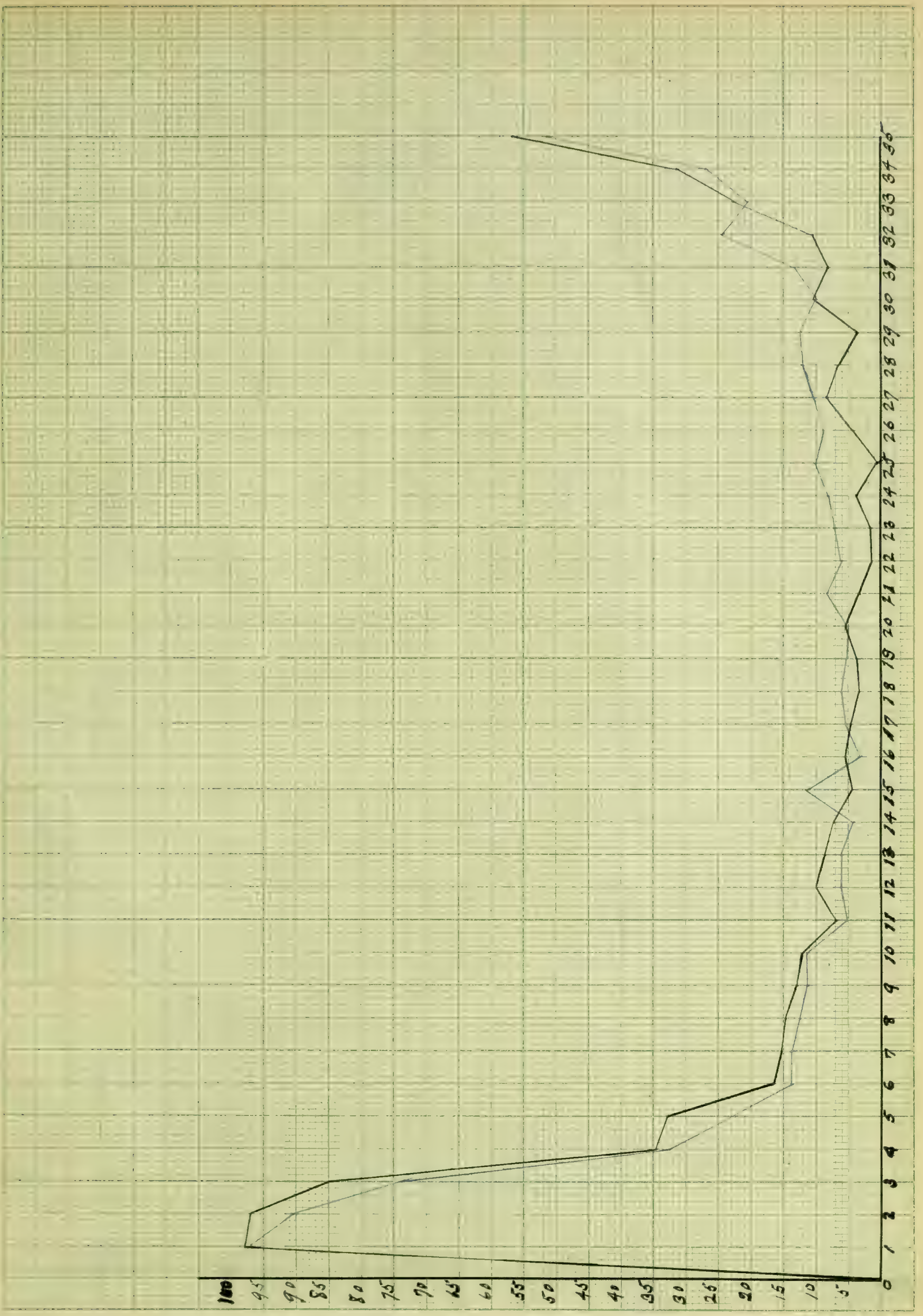
from 18 to 30% was practically constant. The curve representing this table is seen in plate 8.

III.- Summary and Conclusion.

We may thus agree with Vandevelde, that dilute solutions are easily absorbed; the more concentrated the solution, the smaller the power of diffusion. In a saturated solution some of the seeds do not swell and these are the ones that are found to germinate.

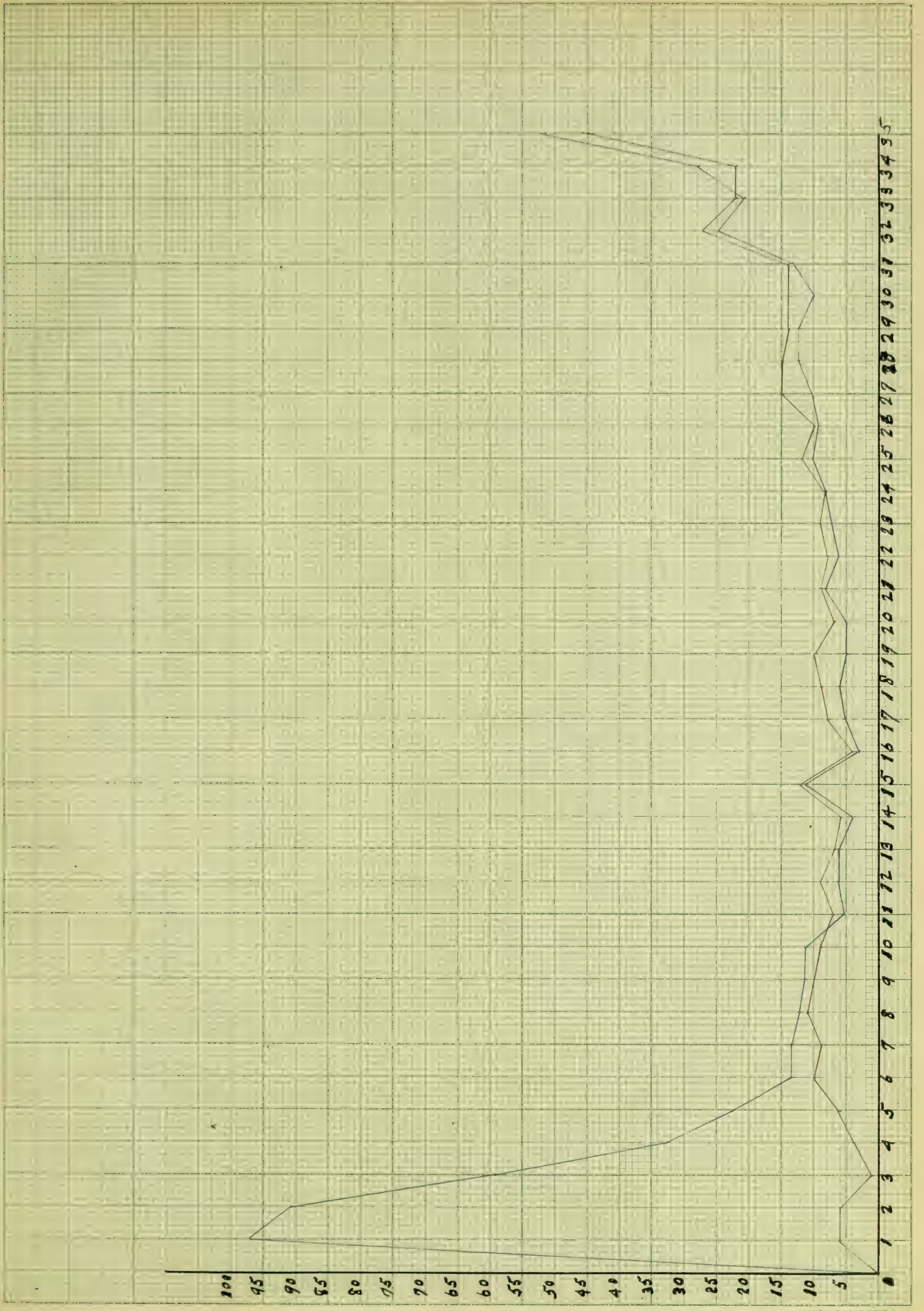
We find, also from the results here tabulated, that the permeability of the seed coats varies some-what with the variety of peas used in the experiments, and after a certain per cent solution is passed all seeds that swell are killed.

Plate I.



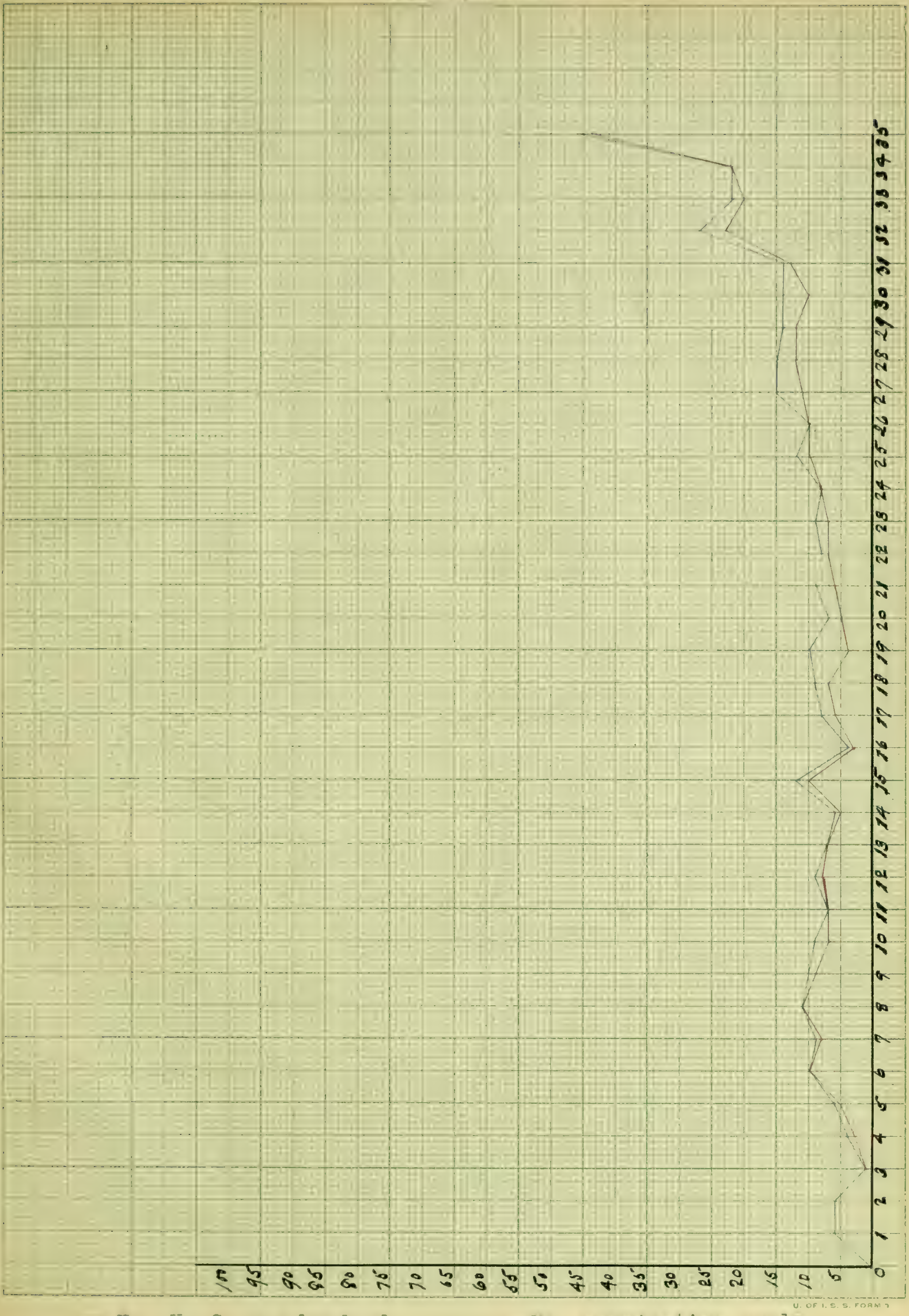
— Curve representing Table No. I.   G% = ordinates
— Curve representing Table No II.   % = abcissas

Plate II. IV.



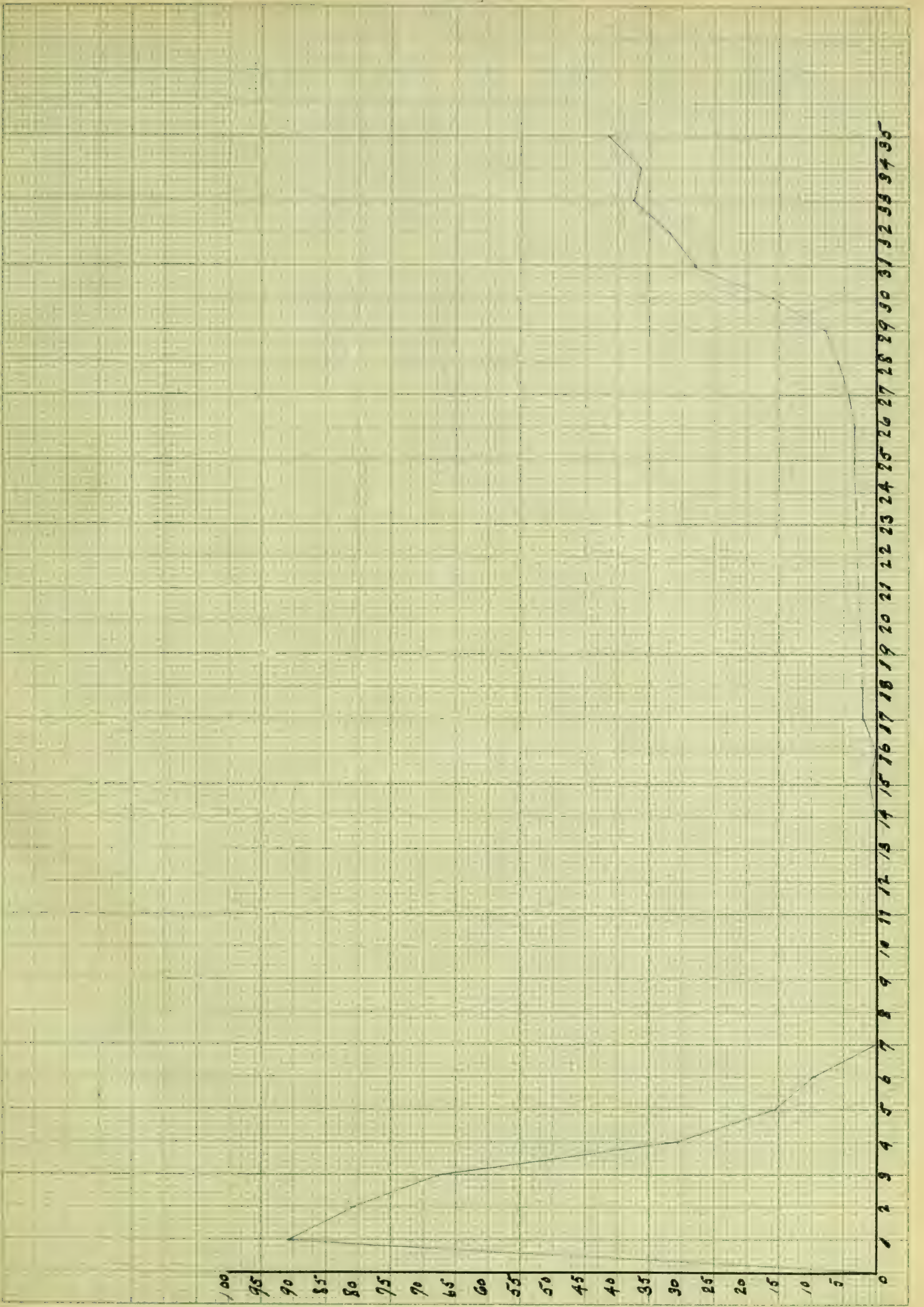
— No. of H. S. per hundred. — No. of germinating seeds.

Plate III. 18.



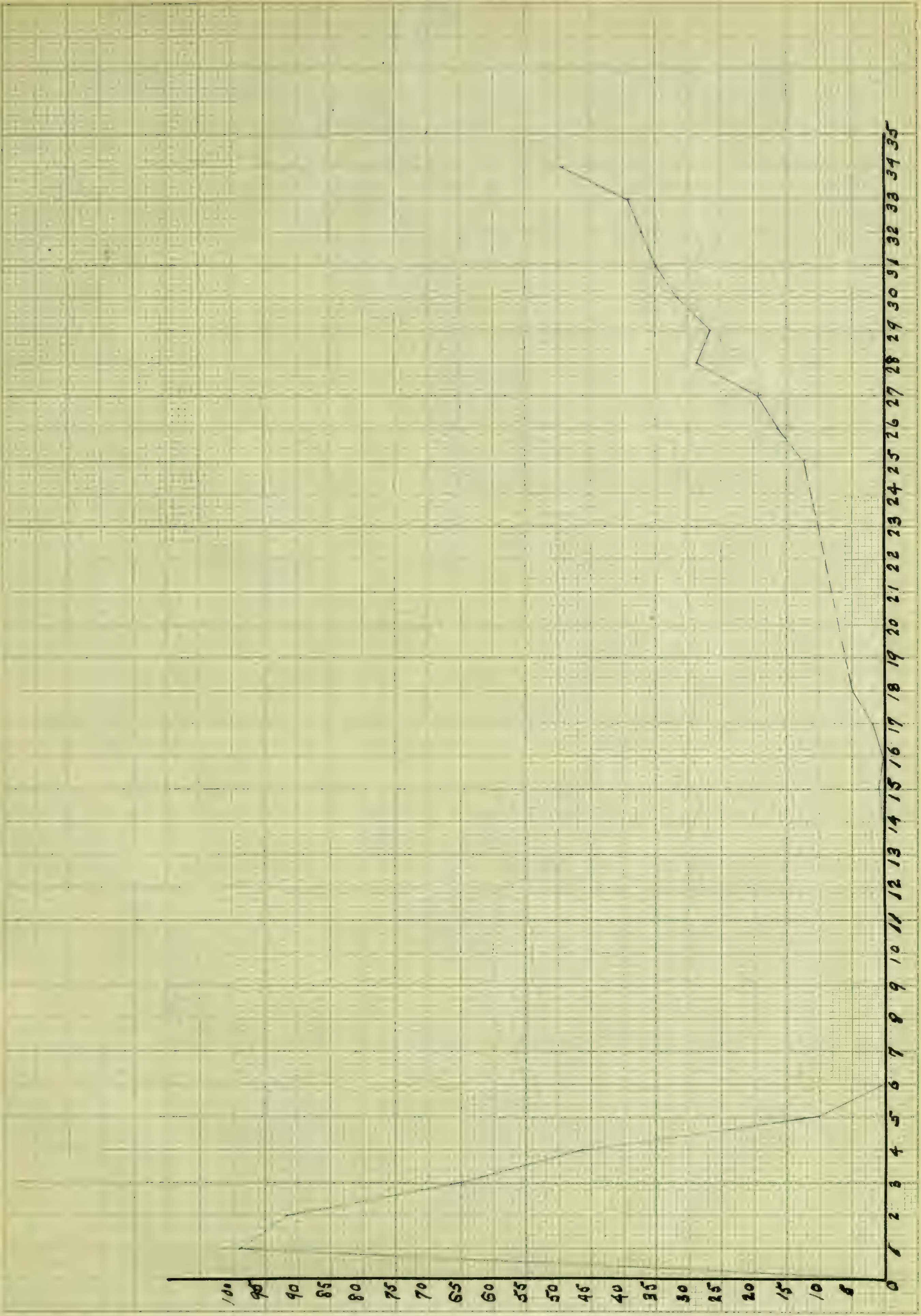
— No. H. S. per hundred. —No. germinating seeds.

Plate IV. 19.



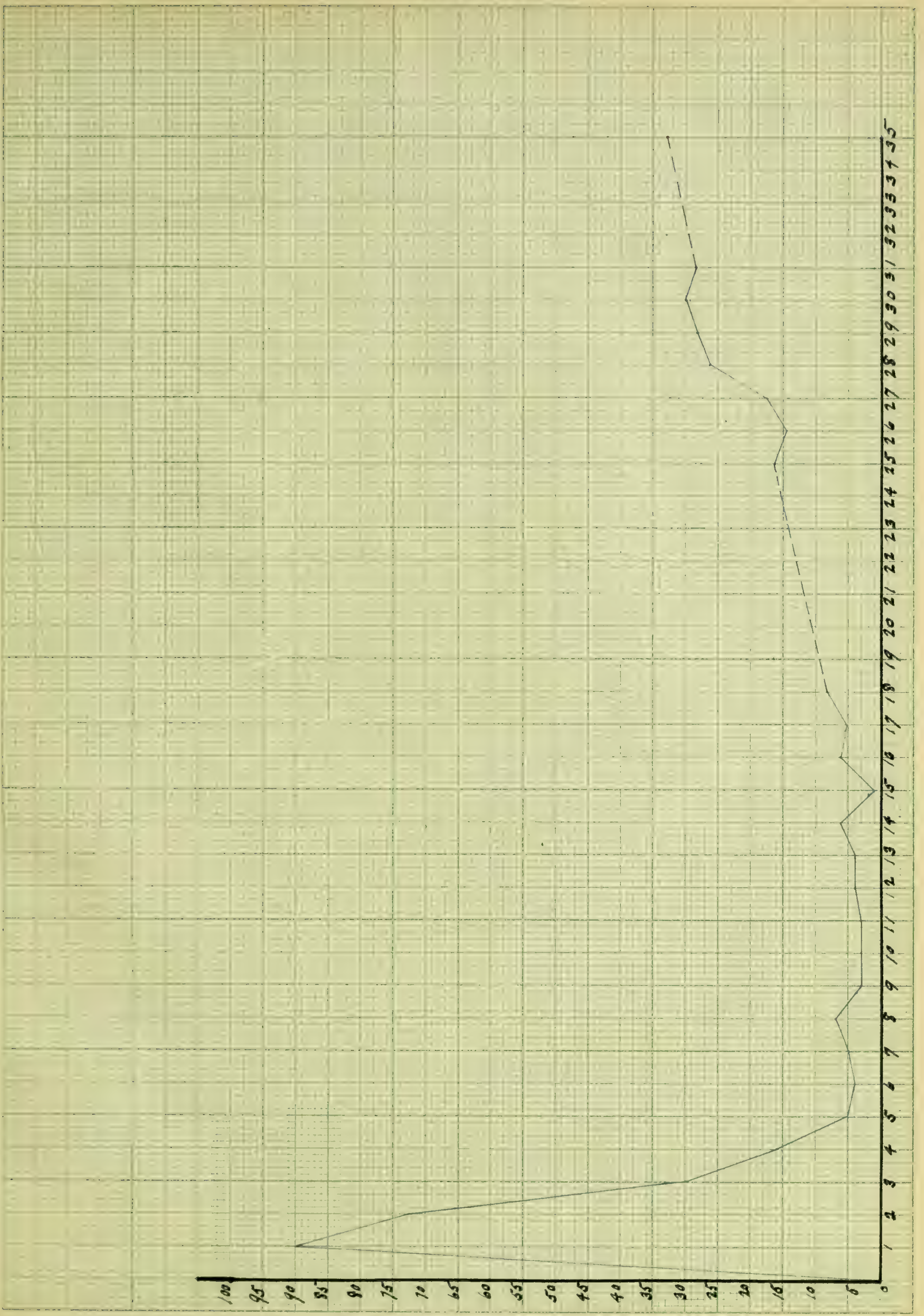
Canada field peas, 2nd. series, G% curve.

Plate 7. 20.

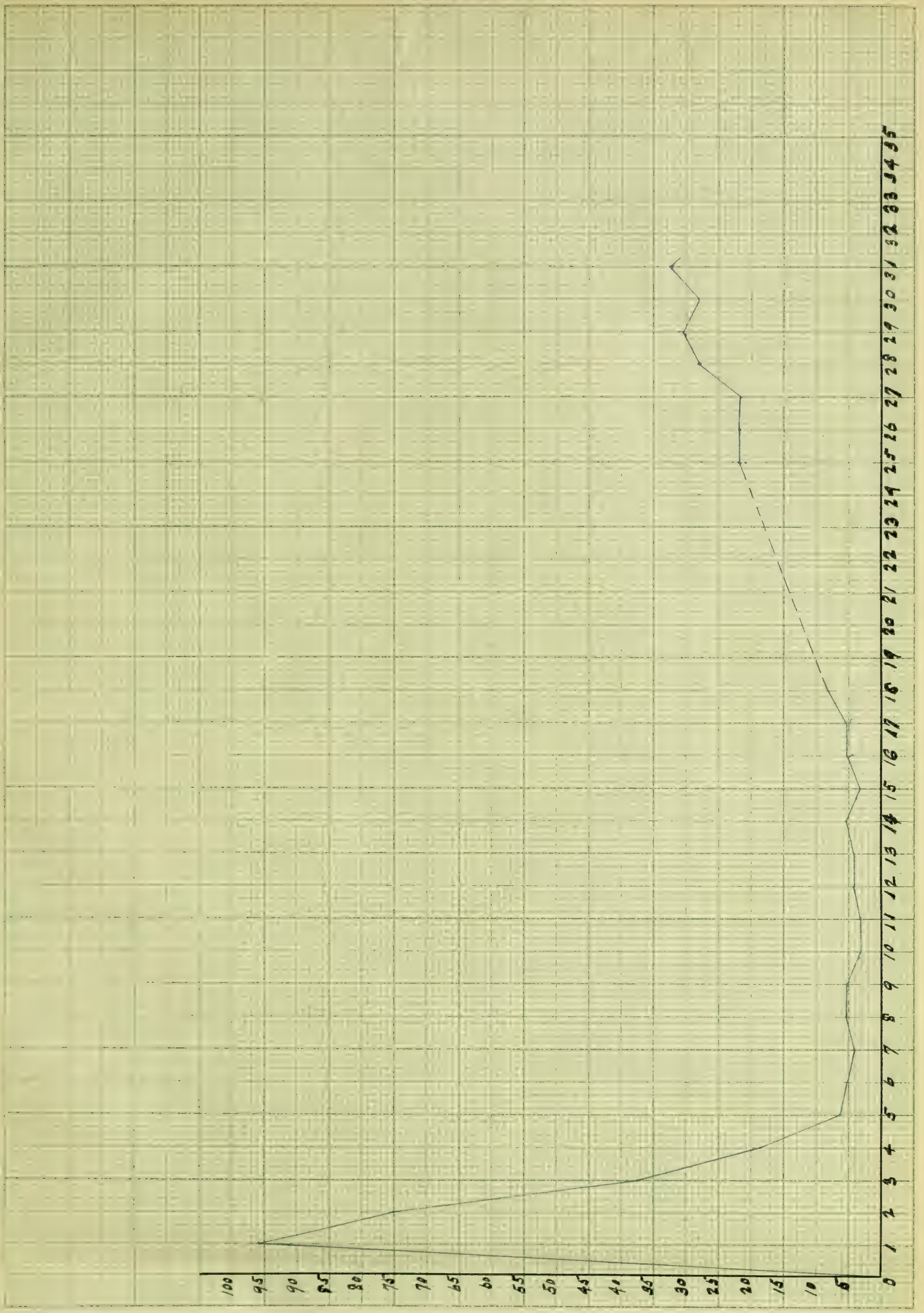


Curve showing G% of Canada field peas soaked 24 hrs. in salt solutions and 24 hrs. in tap H_2O. G%= ordinates. [illegible]=abcissas.

Plate VI. 51.



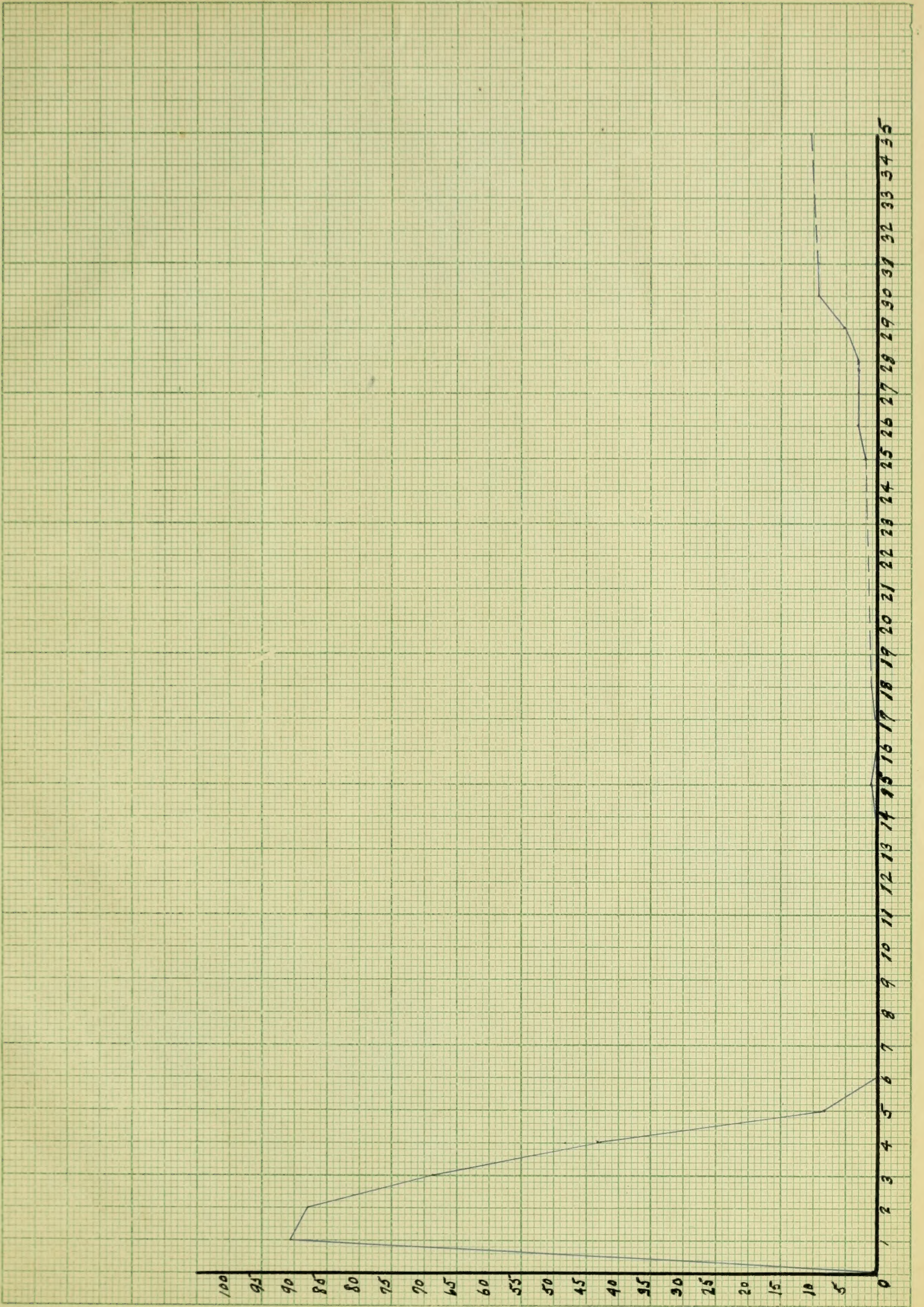
White Marrow Peas. G% = ordinates. % = abcissas.



U. OF I. S. S. FORM 3

White Marrow fat peas--soaked 24 hrs. in salt solutions and 24. hrs. in tap H O. G% = ordinates. % = abcissas.

Plate VIII. 23.



Telephone Pea---G%=ordinates. %=abcissas.

U. OF I. S. S. FORM 3